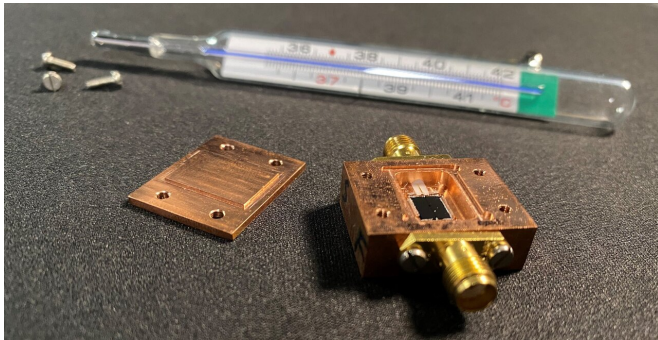


Novel thermometer can accelerate quantum computer development

23 March 2021, by Christian Borg



The new quantum thermometer on a chip, in the foreground. It is probably the world's fastest and most sensitive thermometer for measuring temperature at the cold end of a waveguide at the millikelvin scale, according to the Chalmers researchers. Credit: Claudia Castillo Moreno/Chalmers University of Technology

Researchers at Chalmers University of Technology, Gothenburg, Sweden, have developed a novel type of thermometer that can simply and quickly measure temperatures during quantum calculations with extremely high accuracy. The breakthrough provides a benchmarking tool for quantum computing of great value—and opens up for experiments in the exciting field of quantum thermodynamics.

Key components in quantum computers are coaxial cables and waveguides—structures that guide waveforms and act as the vital connection between the [quantum processor](#) and the classical electronics that control it. Microwave pulses travel along the waveguides to the quantum processor, and are cooled down to extremely [low temperatures](#) along the way. The [waveguide](#) also attenuates and filters the pulses, enabling the extremely sensitive quantum computer to work with stable quantum states.

In order to maximize control over this mechanism,

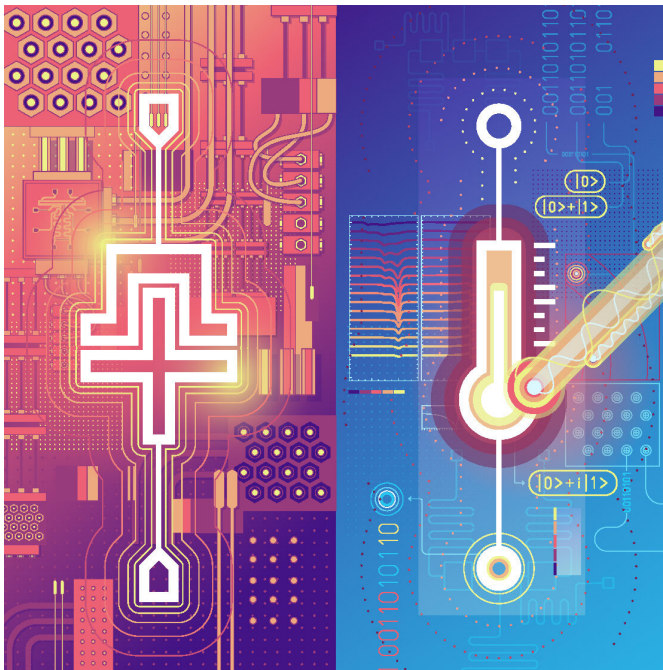
the researchers need to be sure that these waveguides are not carrying noise due to thermal motion of electrons on top of the pulses that they send. In other words, they have to measure the temperature of the electromagnetic fields at the cold end of the microwave waveguides, the point where the controlling pulses are delivered to the computer's qubits. Working at the lowest possible temperature minimizes the risk of introducing errors in the qubits.

Until now, researchers have only been able to measure this temperature indirectly, with relatively large delay. Now, with the Chalmers researchers' novel thermometer, very low temperatures can be measured directly at the receiving end of the waveguide, accurately and with extremely high time resolution.

"Our thermometer is a superconducting circuit, directly connected to the end of the waveguide being measured. It is relatively simple—and probably the world's fastest and most sensitive thermometer for this particular purpose at the millikelvin scale," says Simone Gasparinetti, assistant professor at the Quantum Technology Laboratory, Chalmers University of Technology.

Important for measuring quantum computer performance

The researchers at the Wallenberg Centre for Quantum Technology, WACQT, have the goal to build a quantum computer based on superconducting circuits with at least 100 well-functioning qubits performing correct calculations by 2030. It requires a processor working temperature close to absolute zero, ideally down to 10 millikelvin. The new thermometer gives the researchers an important tool for measuring how good their systems are and what shortcomings exist—a necessary step to be able to refine the technology and achieve their goal.



An artistic impression of the superconducting circuit used in the experiment by Scigliuzzo et al. (left), and of its capability of measuring thermal microwaves at the level of a single excitation quantum (right). Credit: neuroncollective.com / Chalmers University of Technology

"A certain temperature corresponds to a given number of thermal photons, and that number decreases exponentially with temperature. If we succeed in lowering the temperature at the end where the waveguide meets the qubit to 10 millikelvin, the risk of errors in our qubits is reduced drastically," says Per Delsing, Professor at the Department of Microtechnology and Nanoscience, Chalmers University of Technology, and leader of WACQT.

Accurate [temperature](#) measurement is also necessary for suppliers who need to be able to guarantee the quality of their components, for example, cables that are used to handle signals down to quantum states.

New opportunities in the field of quantum thermodynamics

Quantum mechanical phenomena such as superposition, entanglement and decoherence mean a revolution not only for future computing but potentially also in thermodynamics. It may well be that the thermodynamic laws somehow change when working down at the nanoscale in a way that could one day be exploited to produce more powerful engines, faster-charging batteries, and more.

"For 15 to 20 years, people have studied how the laws of thermodynamics might be modified by quantum phenomena, but the search for a genuine quantum advantage in thermodynamics is still open," says Simone Gasparinetti, who recently started his own research group and plans to contribute to this search with a novel range of experiments.

The new thermometer can, for example, measure the scattering of thermal microwaves from a circuit acting as a quantum heat engine or refrigerator.

"Standard thermometers were fundamental for developing classical thermodynamics. We hope that maybe, in the future, our [thermometer](#) will be regarded as pivotal for developing quantum thermodynamics," says Marco Scigliuzzo, doctoral student at the Department of Microtechnology and Nanoscience, Chalmers University of Technology.

More information: Marco Scigliuzzo et al, Primary Thermometry of Propagating Microwaves in the Quantum Regime, *Physical Review X* (2020). DOI: [10.1103/PhysRevX.10.041054](https://doi.org/10.1103/PhysRevX.10.041054)

Provided by Chalmers University of Technology

APA citation: Novel thermometer can accelerate quantum computer development (2021, March 23)
retrieved 6 May 2021 from <https://phys.org/news/2021-03-thermometer-quantum.html>

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